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An Overview of the Application of Reverse Engineering in Selected Fields

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Abstract:

With the continuous development of industrial technology, reverse engineering has become an effective way of research and processing in the development of new products and components. Reverse engineering analyses, deduces and researches the existing products, instruments or systems, and carries out transformation, development and innovation by understanding their principles and design functions. In terms of life, with the gradual enrichment of material life, most of the people are no longer limited to the practicality of material requirements, but also for the appearance of the aesthetic level is also rising. Through the use of reverse engineering technology, such as soap box shape design, motorbike plastic parts design, bicycle handle design and so on. In the field of archaeology, reverse engineering technology is a technology that meets the requirements of archaeology, under the premise of better protection of cultural relics, it plays a pioneering role in the dissemination of culture, especially non-material culture, and provides technical support for human archaeology and ancient text decipherment. For the above contents, this paper will make a comprehensive description, summarise and analyse the application results and development prospects of reverse engineering in some fields.

Keywords: Reverse Engineering, technological innovation, backcasting research, synthesis of narratives, development prospect

1 Introduction

Reverse engineering is widely used in the fields of new product development and product modification design, product imitation, quality analysis and testing, etc. Its role is to shorten the product design and development cycle, accelerate the speed of product replacement; reduce the cost and risk of enterprise development of new products; accelerate the design of product modelling and serialisation and so on.

There are corresponding research progresses in reverse engineering at home and abroad. Firstly, domestic researchers focus on the development of scanning equipment, including high-precision optical scanners and multi-sensor integrated scanning systems. Secondly, domestic researchers are also looking for the application fields of reverse engineering, such as aerospace, automobile manufacturing, archaeological research and so on. Overseas researchers have started to actively develop and optimise reverse engineering software, using new software to process the scanned data of components in a more detailed way and improve the accuracy of reconstructed components.

To sum up, certain progress has been made in the improvement of reverse engineering parts accuracy in China, and the research and application of high-precision scanning equipment, reverse engineering software and accuracy improvement methods have laid the foundation for improving the accuracy of reverse engineering. In the future, further in-depth research and development can be carried out on the technologies and methods that are conducive to improving the accuracy of reverse engineering parts.

2 Summary of key reverse engineering techniques

With the advancement of manufacturing technology, the precision requirements for workpieces are increasing. For reverse engineering, data acquisition, data processing and surface reconstruction are the three most critical technologies.

2.1 *Data acquisition*

Data acquisition is the basis of data processing and model reconstruction, and it is the basic and key technology to realise reverse engineering[1]. Data acquisition devices can generally be divided into two categories: contact and non-contact devices[2]. The specific types are shown in Fig. 1.

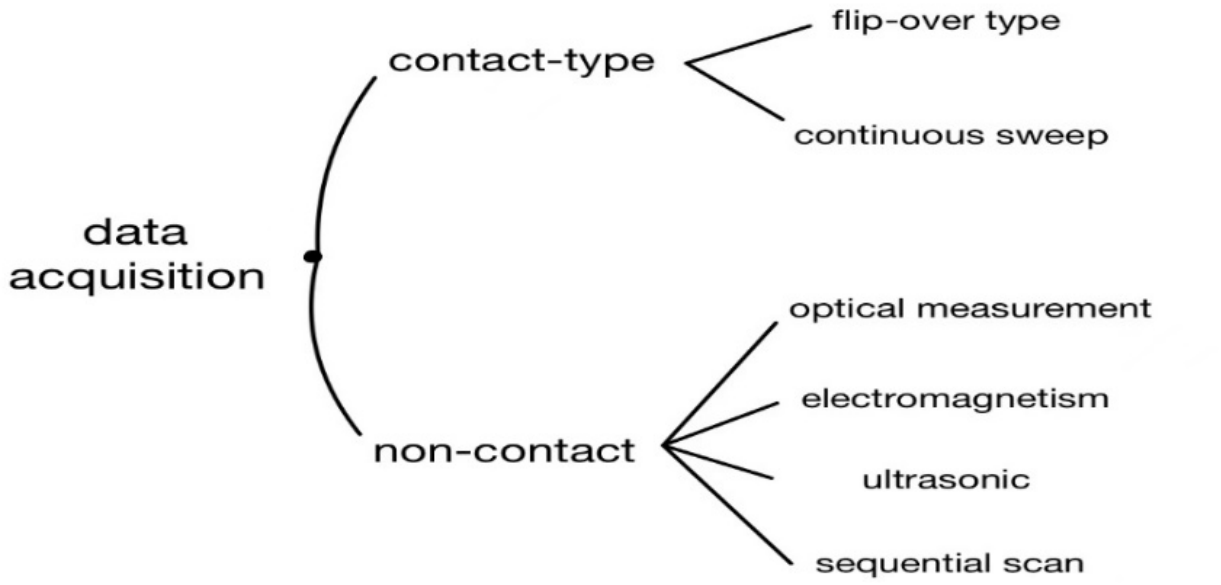


Figure 1 Acquisition Classification

2.2 *Data processing*

In the acquisition of data through 3D scanning, due to the scanning of the data is very large and disorderly, and in the scanning of human operation and environmental factors will affect the accuracy of the data, for this reason, the scanning is carried out several times, and ultimately for the point cloud data obtained by the point cloud de-noising, point cloud streamlining, point cloud alignment and feature recognition of the four steps, the processing of the collected data to organise, prediction and identification of the characteristics of the point cloud, in order to carry out the implementation of the surface reconstruction of the accuracy of the time to improve.

There are three different types of void filling methods: planar, tangential and curvilinear, depending on the characteristics of the surface. When removing local features, the maximum offset of the noise is controlled to be within 0 to 0.5mm in order to ensure the smoothness of the processed point cloud data.

2.3 *Surface reconstruction*

Surface reconstruction is the use of processed point cloud data to reconstruct the feature information of an object's surface and build a new surface based on the original components. There are two common methods used in reconstructing surfaces.

One method is to fit the point cloud data to a curve[2], which generally produces a smooth and accurate surface. Another method is to fit the point cloud data directly to a surface slice, which is then edited by cutting, transitioning, and splicing the resulting surface slice to reconstruct the surface model[2]. This method is less expensive and is generally used for small-scale surface reconstruction and when the accuracy of the reconstructed surface is not required.

3 Ways to Improve the Accuracy of Reverse Engineered Parts

3.1 *Reducing human error to improve accuracy*

Reverse engineering is a method of obtaining information or knowledge by analysing, deconstructing and reconstructing existing products, systems or processes. The most basic thing to improve the accuracy of reverse engineering is to reduce human errors. The first step is to ensure that as much relevant information and data as possible has been obtained, including technical documentation, original products, raw materials and other information. Comprehensive information can enhance the accuracy of reverse engineering. The next step is to carry out verification and correction. Continuous validation and correction of the collected data, comparing data from different sourc-

es to ensure their consistency.

3.2 *Reducing human error to improve accuracy*

3.3 Advancements in scanning technology

Scanning techniques for reverse engineering, from traditional methods to modern advanced techniques, have significantly improved in accuracy and efficiency.

Table 1. Scanning Technical Comparison

TECHNIQUE	BEFORE	NOWADAYS
Scanning speed	Traditional scanning techniques often take longer to complete the scan, especially for complex objects.	Modern 3D scanning technologies typically have faster scanning speeds and the ability to acquire large amounts of data in a short period of time, increasing efficiency.
Resolution	Earlier scanning techniques may have had lower resolution, resulting in less precise data captured	Modern scanning techniques often have higher resolution and can capture finer details, providing more accurate data.
Mobility	Previous scanning equipment was often large, bulky and difficult to use in the field or in complex environments.	Modern 3D scanners are generally lighter, portable and can be more easily applied to a variety of scenarios, including on-site scanning.

3.3.1 *Advances in related software*

Table 2. Software Technology Comparison

TECHNIQUE	BEFORE	NOWADAYS
Features and tools	Early software was often limited in functionality and may only provide basic reverse engineering features such as point cloud processing and simple modeling tools.	Modern software offers more advanced features such as automatic registration, point cloud processing, surface modeling, texture mapping, engineering detail extraction, and more
Efficiency and performance	It is less efficient when dealing with complex data and requires longer computation times.	Process large amounts of data faster, providing higher performance and efficiency.
Automation and intelligence	Manual intervention and processing of data is required, relying on the experience and skill of the operator.	It has a higher degree of automation and utilizes machine learning and artificial intelligence technologies to process data more intelligently

4 Practical applications of reverse engineering in selected fields

4.1 *Reverse engineering in the field of parts processing*

4.1.1 *Improvements in the accuracy of curved par*

4.1.1.1Factors affecting accuracy of curved parts
In recent years, the study of surface accuracy of mechanical parts has received more and more attention in the field of reverse engineering. The process of reverse engineering is shown in Fig. 2[3]. The two main focuses of surface reverse engineering are collecting point cloud data and reconstructing surfaces. The collection accuracy of point cloud data affects the surface accuracy of surface parts, and the construction of reconstructed surfaces affects the accuracy of surface data, which ultimately leads to the advantages and disadvantages of the finished machined mechanical parts.

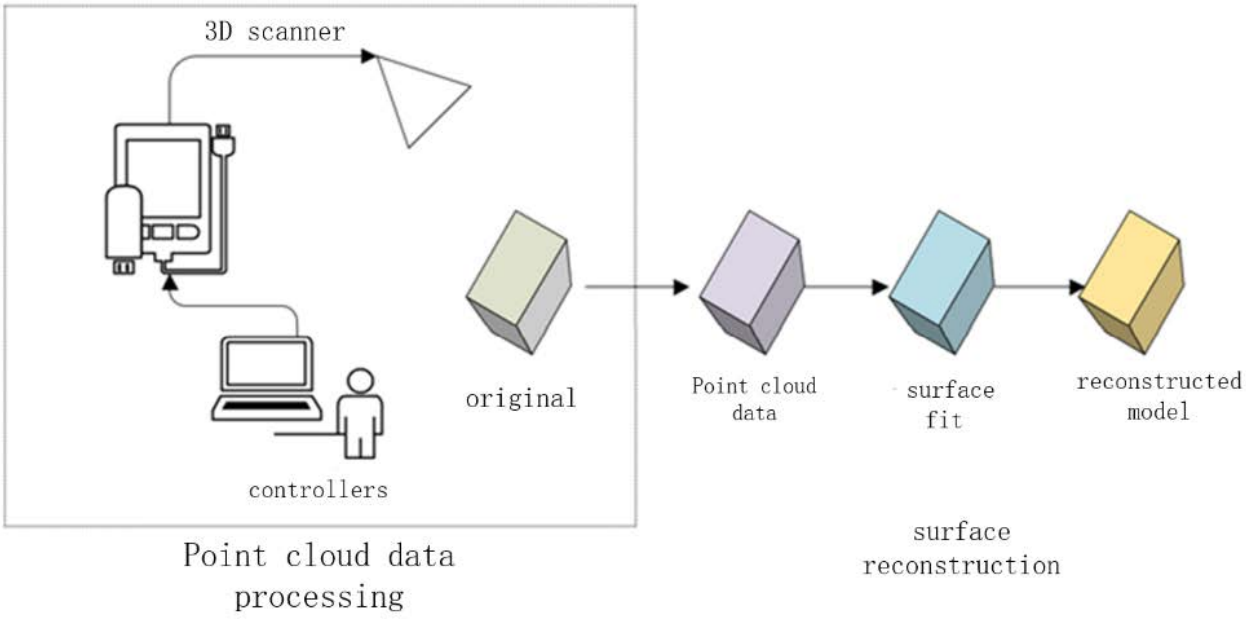


Figure 2 Point cloud data collection and processing

4.1.1.2Ways to enhance curved components

In improving the accuracy of surface parts, firstly, the point cloud data needs to be processed to get the elevation image of the surface. Then the wavelet detail coefficients are used to extract the feature points of the surface, and then the feature points and the space points between the feature points are composed of the data points needed for surface fitting, and finally the control points are back-calculated and the surface reconstruction is carried out, which improves the production accuracy of the curved parts[4].

4.1.2 *Application of reverse engineering in recycling of waste parts and components*

4.1.2.1Defects of current remanufacturing of waste parts and components

At present, for the remanufacturing of waste parts and components is basically manually involved, with a strong dependence on experience[4], and different workers can't guarantee exactly the same machining accuracy, such as grinding depth, lamination thickness, etc., which leads to low efficiency, poor reliability, poor quality and other problems in the repair process of remanufacturing parts and components. In addition, because the repair process is irreversible, the repair process may lead to the direct scrapping of parts due to improper operation.

4.1.2.2Recycling process of used parts based on reverse engineering

The recycling process of used parts using reverse engineering is shown in Figure 3[4]. Through the collection of surface data, the point cloud data is pre-processed and then modelled, and then the constructed damage model is compared and contrasted with the original CAD model to select whether to use additive or subtractive repair, and finally the recycled part model is derived.

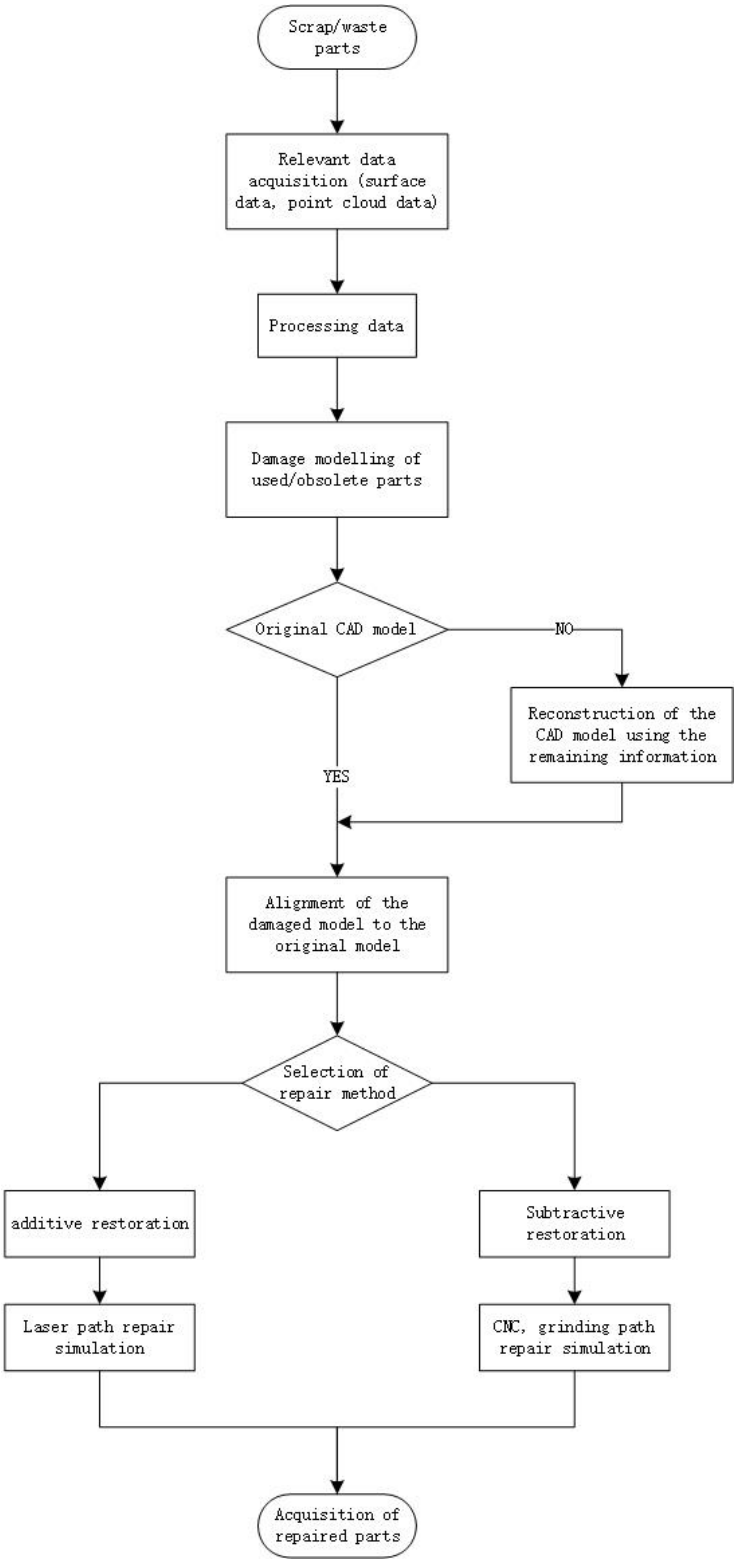


Figure 3 Recycling Flow Chart

4.1.2.3Key technologies of reverse engineering in recycling of used parts and components

Reverse engineering related technologies are used in the process of reverse engineering assisted recycling of used parts. Before recycling of used parts, different parts are analysed and different technical methods are selected to reconstruct their models[4], and the key technologies are shown in Figure 4.

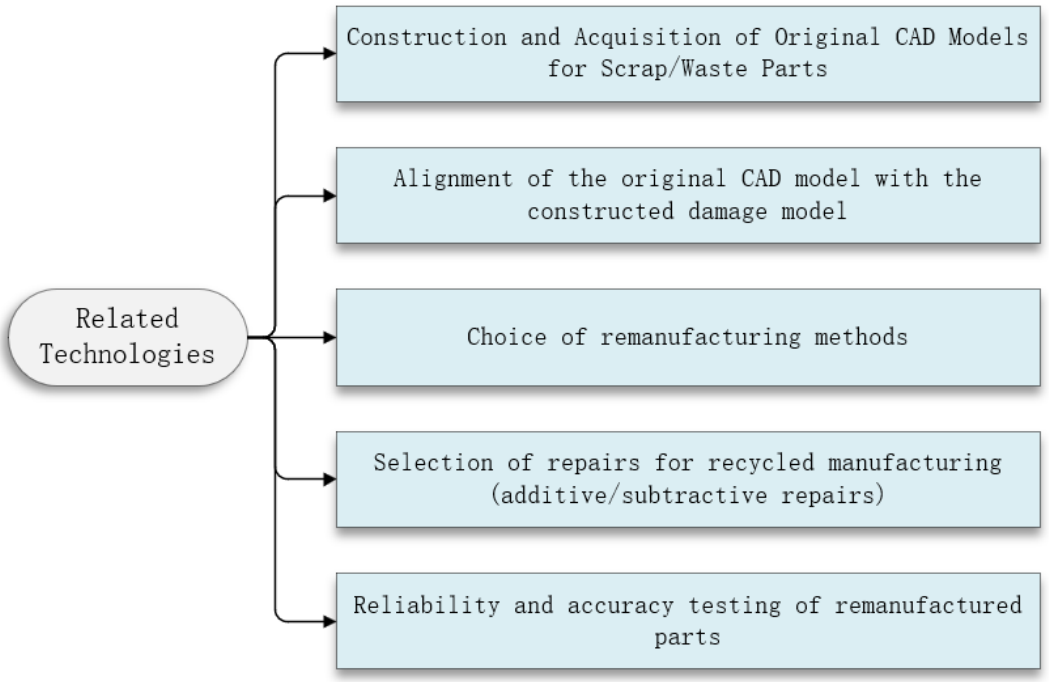


Figure 4 Key technologies for recycling

4.2 *Application of reverse engineering in industrial design and manufacturing*

4.2.1 *Application of reverse engineering in fan industry*

Reverse engineering technology is a technology that analyses and reconstructs existing products and then upgrades them. At present, reverse engineering technology has become an important technology in the fan industry to update, innovate and transform products, gradually promoting the development and innovation of fan products. The application areas of reverse engineering in the wind turbine industry are shown in Table 3 below[5].

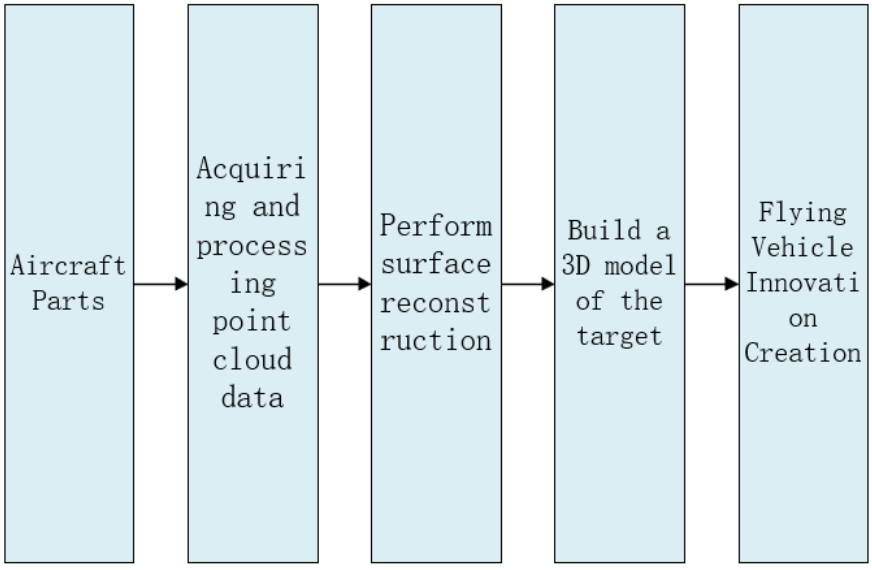
Table 3. Areas of application

	New Product Design	Product upgrades	Spare parts manufacturing	Product Quality Inspection
concrete content	It is currently very difficult for wind turbine companies to develop a completely new set of model machines due to the long and inefficient development cycle time. The use of reverse engineering can speed up development and updates.	For the current domestic wind turbine exposed defects for upgrading, one is to reduce the cost of re-development of new products, the second is to make the domestic wind turbine enterprises to obtain a good opportunity for development.	Spare parts extend the life of the fan during its use. Reverse engineering is used to manufacture and improve the original product without drawings and shortcomings.	Due to the special characteristics of the fan blade structure, the inspection using traditional means will have a large error. The use of point cloud data preprocessing in reverse engineering and model construction can be used to better inspect the quality of the product.

4.2.2 *Application of Reverse Engineering in Small Quadrotor Vehicles*

4.2.2.1Design process of small quadcopter

Reverse engineering software Geomagic Design X is used to process the point cloud data, then surface construction, modify and optimise the model according to the design requirements, and finally complete the innovative design of the aircraft.



The design flow of the small quadcopter is shown in Figure 5[6].

Figure 5 Design Flow of the Small Duadcopter

4.2.2.2Data Acquisition and Processing of the Flight Surface

Firstly, fix the fixed point, use VXelements software to set relevant parameters, scan the surface of the aircraft, and finally acquire relevant data.

The processing of the point cloud data consists of six parts: noise removal, data filling, data simplification, feature removal, point cloud alignment, smoothing and smoothing[6]. Among them, data filling has three different methods of void filling: planar, tangential and curvature depending on the different features of different object surfaces. When removing local features, the maximum offset value of the control noise is generally within 0 to 0.5mm in order to ensure the smoothness of the processed point cloud data.

4.3 *Application of reverse engineering in the field of life*

4.3.1 *Application of reverse engineering in motorbike plastic appearance design*

With the intensification of market competition, customers for new products in the practicality and performance of the basis for the appearance of the design requirements are also higher, so more personalised, more unique product design more attractive to customers. In order to adapt to the fast-changing market environment, most enterprises borrow reverse engineering technology to provide inspiration and ideas for product development and innovation.

In the case of motorbike appearance design, the product appearance is designed first, then the target product is modelled, and finally processed with digital apparatus for production.

The specific process is shown in Figure 6[7].

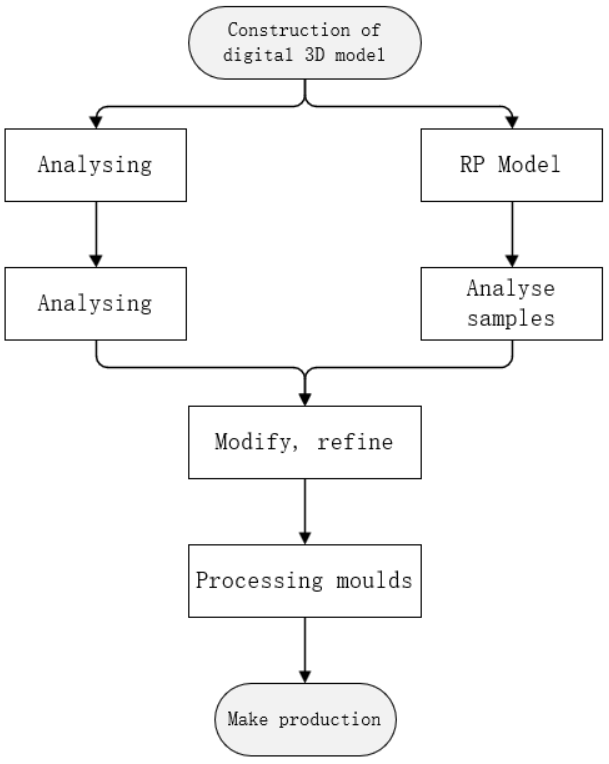


Figure 6 Appearance Design Process

4.3.2 *The application of reverse engineering in the design of soap box*

The application of reverse engineering in life is very wide, in addition to the appearance design of motorbike mentioned above, there are also applications in the design of daily necessities such as soap box.

In the design process of the soap box, the first is the three-dimensional data acquisition of the soap box, Xia Huifang et al [6] used the Japanese Konica Minolta three-dimensional scanner RANGE7 for data acquisition of the soap box[8]. This instrument collects the surface data by emitting laser lines at different angles, and collects the surface data through different laser beams reflected back, and finally obtains the complete point cloud data.In the design of soap box, the process of reverse engineering technique is similar to that of motorbike exterior design, recycling of discarded parts and so on as mentioned above, both of them use the point cloud data for the creation of 3D model, and the final difference lies in the colouring of the soap box[8].

4.3.3 *Application of reverse engineering in bicycle handle design*

The process of reverse engineering in the design of bicycle handle is basically the same as above, the special point to note is that due to the ergonomics and increase friction to increase the safety of the premise of the bicycle handle in the surface is not smooth and flat, for the surface of the surface of the existence of concave-convex surface details, the need for multiple scans of the surface in order to obtain a complete surface point cloud data.

Zhu Hongping et al[9] proposed to collect the surface data of bicycle handlebar by using Ateck handheld laser scanner. The specific workflow is listed below:

- In order to increase the reliability of the data, the scanning field of view of the scanner needs to be adjusted before recording the point cloud data to ensure that the collected point cloud data is more complete.
- Due to the special requirements of bicycle handles, which are generally made of black or metal, there is generally a large error in scanning black or metal objects with a laser scanner, so the developer should be sprayed before scanning.
- Due to the limited field of view of the hand-held scanner, if it will be fixed will not be able to get the complete surface data, so in the scanning process should be rotated, change the angle, after several scans to collect the data obtained.

4.4 *Application of reverse engineering in archaeological field*

In archaeology, heritage protection is an important and meaningful research direction. Reasonable protection of cultural relics, firstly, can be more complete preservation of valuable cultural relics with historical precipitation, and secondly, extend the preservation time of cultural relics for experts and professionals to decipher cultural relics, thus playing an important role in the development of anthropology.

4.4.1 *Application status of reverse engineering in cultural relics conservation*

In recent years, researchers and scholars at home and abroad have made significant contributions to cultural relics protection and cultural heritage using reverse engineering technology.

Gao Xiufen[10] used reverse engineering technology to carry out 3D modelling of national costume ornaments, instruments of ethnic minorities and non-heritage artifacts, preserved them using electronic technology, and made use of the medium of the network to better disseminate traditional culture while protecting non-heritage items. Shu Huan proposed the use of reverse engineering technology in the restoration and protection of terracotta warriors and horses, scanning the fragments and cracks by three bits, and restoring them through comparison, which provides new ideas and new methods for the protection of terracotta warriors and horses. Similar to Shu Huan[11], Yu Jian[12] proposed the use of 3D scanning for contactless

information acquisition of bronze, and the use of reverse engineering technology to collate and process the acquired information to obtain a reconstruction model. This method avoids the direct contact and secondary damage of traditional restoration of bronzes, and protects the cultural relics in a better and more complete way.

4.4.2 *The significance of reverse engineering for the protection of cultural relics and cultural dissemination*

In recent years, the literature and innovative ideas show that reverse engineering has a pioneering role in heritage protection, without delaying the restoration of cultural relics and cultural relics interpretation under the premise of better preservation of cultural relics of the original appearance, and at the same time, after the 3D modeling and electronic information transfer, so that more intangible cultural heritage has been widely disseminated, and more people, especially young people on our country's long history of culture with a richer understanding to enhance the sense of cultural identity and cultural self-confidence. cultural identity and cultural confidence.

5 Summarise the significance of reverse engineering technology for human beings

Reverse engineering analyses, backtracks and researches existing product instruments or systems, and develops and innovates them by understanding their principles and design functions. In terms of scientific and technological innovation and progress, reverse engineering can help people understand and learn from existing technologies and designs, so as to innovate the relevant technologies, and promote the development of relevant technologies through in-depth study of existing products and technologies, and the creation of aspects that can be improved and optimised. In terms of life, with the gradual enrichment of material life, most of the people are no longer confined to the practicality of material requirements, but also for the appearance of the aesthetic level is also rising. Through the use of reverse engineering technology, such as the above mentioned soap box shape design, motorbike plastic parts design, bicycle handle design, etc., designers from the perspective of serving the public, and aesthetic logic, reconstructing the design of innovative new products. In the field of archaeology, reverse engineering is a technology that meets the requirements of archaeology, plays a pioneering role in the dissemination of culture, especially non-material culture, under the premise of better protection of cultural relics, and provides technical support for human archaeology and the deciphering of ancient texts.

6 Prospects for the future development of reverse engineering

Reverse engineering has a very promising future, firstly because it can be applied in many fields, and secondly because it allows innovation in various fields to provide new ideas and channels. By summarising the different fields mentioned above, the following predictions are made about the possible future development trends and prospects of reverse engineering:

- Promotional role for technological innovation. With the continuous development and advancement of science and technology, reverse engineering technology is also advancing in terms of technical means, including computational power, intelligent algorithms, and precision control. These make reverse engineering more efficient and reliable.
- Development of digital model reproduction. Through reverse engineering, laser scanning and data collection and processing, digital modelling and replication of fifteen objects are realized, which provides basic data for virtual reality and augmented reality technology.
- Enabling stronger intellectual property protection. In today's environment of continuous technological progress, the demand for the protection of intellectual property rights is gradually increasing. Reverse engineering plays a vital role in identifying and preventing intellectual property infringement through its special back-propagation characteristics.

lThe application in the industrial field will be more extensive. The application prospect of reverse engineering in industrial design is very wide, which can help enterprises to reduce development cost, improve product quality and increase innovation efficiency, and also play an important role in the subsequent maintenance and upgrading of products.

7 Conclusion

Overall, reverse engineering will continue to develop in many areas as technology continues to advance and explore, providing strong support for technological innovation, problem solving, and subsequent maintenance. At the same time, it is important to respect privacy, ethics, and intellectual property rights when using reverse engineering as a tool for human development.

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